PHYSIOLOGICAL ASSESSMENT OF THE RNZ AIR FORCE CONSTANT WEAR IMMERSION GARMENT

James D. Cotter, Stephen J. Legg[§], and Nigel AS. Taylor
Division of Sciences, University of Otago,
New Zealand.

INTRODUCTION

The Royal New Zealand Air Force (RNZAF) has developed a Gortex® non-insulated, constant wear immersion suit (CWIS), with integral booties, for use by strike and rotary wing aircrews. Assessment of such thermal garments may be conducted using modelling or physiological testing. While testing human subjects is controversial, the complete interaction between the environment, the CWIS and the wearer may best be obtained using human immersions. This is exemplified when water ingress is considered. Since ingress critically affects dry-suit insulation, both modelling and calm water tests may fail to adequately reflect the result of realistic stresses upon water seal iategrity. The purpose of this project was to evaluate the thermal performance of the CWIS using human subjects during both laboratory and open sea trials.

METHODS

Six subjects were immersed to neck level in a 2 m^3 tank. Water temperature was controlled at 4.99 ±0.13°C. Subjects wore each of two clothing ensembles representing minimal and maximal undergarment configurations: (i) long cotton underwear, one pair of woollen socks, non-integral gloves, and CWIS; and (ii) long cotton, long and short woollen underwear (9 mm pile), two pairs of woollen socks, non-integral gloves, and CWIS. The same subjects were immersed in open ocean (U.89 ±0.69°C, sea state 0-2, Beaufort wind 0-4) wearing undergarment configuration (ii) without the second pair of socks and with boots, coverall, Mk12 parachute. harness/lifejacket, G-trousers, and helmet.

Rectal and 10 skin temperatures were monitored with thermistor probes (Thermonetics) and stored using a Grant Squirrel datalogger (1200 Series), while heart rate was recorded using a Sportester (PE3000R). Thwe data were sampled at fifteen second intervals. Water temperature was monitored 30 an anterior to the subject. Skinfolds were recorded at the skin temperature sites in addition to the chest, suprailiac, and calf. Expired gases were collected using Douglas bags (laboratory trials only) and subsequently analysed for O_2 and CO_2 content. Whole body thermal sensation, and total and regional discomfort were monitored. Garment and body insulations were derived (except for field trials). Trials were terminated either by volitional withdrawal, T_{re} = 35°C, local skin temperature less than 7°C for three minutes, or elapsed time (3 hr laboratory trials, and 2 hr ocean trials). Hotellings T_2 statistic was used to evaluate differences between ensembles, while polynomial regression analysis (half-interval method) was used to predict time to hypothermia (T_{re} = 35°C) and time of useful consciousness (T_{re} = 34°C).

RESULTS AND DISCUSSION

All laboratory trials, except one, were prematurely terminated due to: T_{re} less than 35°C in both trials (subject 4); T_{toe} less than 7°C twice in subjects 1, 3, 5, 6; and extreme thermal discomfort in ensemble (i) for subject 2, who completed 3 hr in ensemble (ii). Subjects 2 and 5 completed the sea trails while subjects 1, 4 and

6 became hypothermic and subject 3 was withdrawn for non-thermal safety reasons. Subjects 3, 5 and 6 stabilized T_{re} above 35°C, therefore no statistics are shown in Table 1. Water ingress was minimal in the laboratory, but was estimated to exceed 3 litres in 4 subjects in the sea.

Mean body tissue insulation was 0.058 (±0.025) °C.W $^{-1}$.m^2 for both ensembles at 15 min, and 0.061 (±0.008) and 0.069 (±0.023) °C.W $^{-1}$.m^2 for ensemble (i) and (ii) at 42.5 min (respectively. On average, the woollen undergarments increased clothing insulation by factor of about 3.5, with respective mean garment insulation at 42.5 min being 0.035 (20.002) and 0.130 (±0.030) °C.W $^{-1}$.m^2. Metabolic heat production, was four-fold higher than at 15 min for ensemble (i) and two-fold higher for ensemble (ii).

Table 1: Test durations, and predicted time to hypothermia and time of useful consciousness (minutes (±SD)).

Condition	Test duration	Time to hypothermia	Time of useful consciousness
Lab (i)	58.3 (10.2)*	70.6 (19.3)*	86.6 (19.5)*
Lab (ii)	141.7 (75.4)	200.8 (50.0)	269.2 (77.9)
Sea	109.0 (15.0)	97.4 (9.4)	118.8 (7.8)

* Difference between Lab (i) and (ii) significant for $\alpha = 0.05$.

Chest temperature displayed between-subject variation that corresponded with survival time estimation. Similarly, skinfold thickness correlations with rectal cooling were Consistently higher for local sites (lateral chest, medial chest, front thigh, triceps) than for the sum of ten skinfolds. It was not surprising that the predicted time of useful consciousness (laboratory) was considerably lower than might be predicted using body fat approximations for the 10th percentile (Nunneley et al. 1985). While localized skinfold thickness appeared a good indicator of rectal cooling rate, the poor association between skinfold thickness (measured by calipers) and total body subcutaneous fat restricts its use as a general predictor of survival the.

Sea trials confirmed that thermal protection was degraded by wave-induffid water ingress, serving to further reduce predicted survival times (Table 1). Half of our subjects may have lost useful consciousness by about 4.5 hr, yet RNZAF aircrew are expected to survive for 12 hr before being recovered from an open sea ditching. The thermoregulatory responses of these subjects was inadequate to provide thermal homeostasis above 35°C. It is recommended that the water seals undergo modification to minimize leakage, particularly at the neck, and that aircrew be exposed to cold stress tests to identify crew in whom thermoregulatory responses are not conducive to survival during extended immersions. Such crew could then be provided with CWIS modifications and undergarments to enhance survival.

REFERENCE

Nunneley, S.A., Wissler, E.H. and Allan, J.R., Immersion cooling: Effect of clothing and skinfold thickness. Aviat. Space. Environ. Med., 56: 1177-1182, 1985.

§ Present address: Defence Environmental Medicine Unit, RNZAF, Base Auckland, New Zealand.